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Application of Marvin's Periodocrite to Rainfall Periodicity.*

BY DINSMORE ALTER.

(Plates VII and VIII.)

PROFESSOR MARVIN has recently [1] published a criterion for discrimination between real periodicities and fortuitous ones. This criterion, called by him the periodocrite, seems to me to fill a real need, and I hope that it, or a slight modification of it, may be adopted generally for such purposes.

If the data covers q of the suspected cycles they are arranged in q rows and p columns. The total number of observations is N. $\sigma_o = \pm \sqrt{\frac{\Sigma V_n^2}{N}} = \frac{\Sigma V_n}{.7979\,N}$ is then formed. Let n be any number of the rows or cycles. The mean is taken of the n observations, in each column, and $\sigma_n = \pm \sqrt{\frac{\Sigma V^2}{n}} = \frac{\Sigma V}{.7979\,n}$ is formed. The ratios $\frac{\sigma_n}{\sigma_o}$ are plotted as ordinates and $\frac{1}{\sqrt{n}}$ as abscissæ. "When y is substantially and consistently greater than x a real periodicity is indicated of greater or less amplitude."

In the first of these two papers published here I have given two tables continuing the work of the previous paper on a rainfall period equalling one-ninth the principal sun-spot period. The first of these tables shows the percentages of normal for each phase of each of twenty-four consecutive

* Received for publication August 5, 1921.

1. Monthly Weather Review, March, 1921, pp. 115-124.

cycles in the eastern third of the United States. The second table shows the same for each of seventeen consecutive cycles of a large western group. These tables are peculiarly well adapted for application of Professor Marvin's Periodocrite.

In table 1 of this paper I have formed the means of the first n cycles for each column of the Eastern group table described above, allowing n to assume each integral value from one to twenty-four. These means are the tabular values printed under each phase number. From these I have computed x and y, beginning with $n = 3$. In table 2 I have done the same thing for the Western group.

The last columns show the ratios y/x. Each of these thirty-five ratios is greater than one, the mean for the first table being about 1.4 and for the second about 1.2.

In plate VII I have shown these results graphically, and for purposes of comparison have copied the curves representing the annual cycles of Washington, D. C., and of Boston from the figure given by Professor Marvin in his paper.

The following has no connection with the application I have just made of the periodocrite to rainfall, but I believe that a slight modification of its graphical representation, not in any way changing its principle nor the method of analysis, will make it even more useful to discriminate between accidental and real periodicities of small amplitude.

When x is plotted as $\frac{1}{\sqrt{n}}$ the abscissæ corresponding to successive values of n become very closely crowded together, so much so that in the case of of 24 cycles the last half of them are represented by a very short portion of the curve, one easily overlooked in comparison with the much longer part representing the first half of the data. For a larger number of cycles the case becomes even worse. Yet these are the cycles in which accidental errors have been damped, to a large extent, and in which any true periodicity of small amplitude will show itself most clearly. Furthermore $\frac{\sigma_n}{\sigma_0}$ has become small, if the amplitude of a real periodicity is small, and the distance that is plotted above the line of perfect fortuity seems to the eye to be negligible, despite the fact that y/x, the real criterion, may rapidly be increasing to a large value.

I would therefore suggest that the graphical representation be changed to $X = n$ and $Y = y/x$. If this be done Y will, in general, decrease when X is small, even though there be a real periodicity of small amplitude superimposed on observations with large accidental errors; then, when n has become large enough to damp out the major portion of these errors, increase rapidly, no matter how small the real periodicity, to an infinite limit. If, however, there are no real periodicity Y will approach one as a limit. Such cases as the annual cycle at Boston, where the amplitude is small but where n has become very large, and which look doubtful as plotted by Professor Marvin, despite our knowledge of their truth, will show clearly the differences between themselves and accidental combinations. In plate VIII I have replotted in this way the four curves of plate VII.

In conclusion, I wish to warn against a possible misunderstanding on the part of the reader concerning Professor Marvin's statement on page 118 of his article mentioned above, that "other sequences 15 months, 16 months, one-ninth the variable sun-spot period, like the circles, all fall in the class of perfect fortuity." In a letter to me of later date he says: "I would like to know what the testimony of the periodocrite principle would be in reference to the alleged cycles you have examined. I am sure it is easily possible for you to make the application, as you have all the tabulations and data most fully worked up, whereas for me to do the thing myself would mean practically the entire duplication of the work you have already done." It is evident from this statement that he means to refer only to the five towns in Iowa and not, as some might erroneously infer, to the great mass of data I have used.

TABLE 1.—Eastern group rainfall.

n	1	2	3	4	5	6	7	8	9	16	11	12	13	14	15	y	x	$\frac{y}{x}$
1.....	74	258	64	129	127	122	110	71	66	224	142	116	94	184	117	.....	.....	.....
2.....	82	178	87	124	94	116	110	87	63	167	138	92	61	138	104	.....	.....	.....
3.....	84	153	86	132	94	125	121	94	69	150	121	85	71	122	110	1.10	58	1.90
4.....	92	133	89	124	96	108	127	92	73	134	130	89	76	111	102	.79	.50	1.58
5.....	91	125	90	114	92	109	117	100	79	128	122	97	73	114	106	.61	.45	1.35
6.....	91	117	97	118	99	113	119	97	85	118	114	93	73	112	109	.53	.41	1,29
7.....	98	110	93	118	96	121	111	100	93	120	111	98	76	107	111	.47	.38	1.24
8.....	104	116	89	114	99	125	114	97	88	117	110	101	74	102	114	.50	.35	1.43
9.....	103	117	88	112	100	125	116	98	90	114	102	104	74	99	117	.48	.33	1.45
10.....	103	119	89	107	100	122	117	98	89	111	104	100	77	98	113	.44	.32	1.38
11.....	100	119	91	104	100	123	111	96	90	109	103	99	75	95	113	.42	.30	1.40
12.....	101	115	94	102	98	122	112	95	93	106	106	95	76	98	114	.39	.29	1.34
13.....	100	113	95	101	94	118	113	96	93	105	105	95	77	99	116	.37	.28	1.32
14.....	100	117	96	100	96	119	110	95	92	104	104	94	78	97	114	.37	.27	1.37
15.....	103	116	97	99	99	118	108	94	94	107	102	93	80	100	115	.35	.26	1.35
16.....	103	114	100	100	96	115	111	93	95	106	100	94	81	98	117	.34	.25	1.36
17.....	104	114	103	99	100	115	110	92	96	106	100	94	80	97	115	.33	.24	1.37
18.....	102	114	102	98	99	115	110	92	97	103	100	93	81	96	114	.32	.23	1.39
19.....	103	114	102	99	99	115	107	94	98	101	101	92	82	97	115	.32	.22	1.45
20.....	104	114	104	99	100	115	106	93	98	103	101	92	82	100	114	.31	.22	1.41
21.....	106	115	103	101	100	115	107	92	98	103	100	91	81	98	112	.31	.22	1.41
22.....	108	114	104	102	100	113	106	91	97	102	100	92	79	98	112	.31	.21	1.48
23.....	108	114	103	101	101	112	105	91	95	101	101	90	79	98	113	.31	.21	1.48
24.....	108	115	105	103	101	110	107	94	96	100	101	90	81	97	112	31	.20	1.50

TABLE 2.—Pacific group rainfall.

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	y	x	$\frac{y}{x}$
1	114	50	14	70	45	187	105	94	147	250	215	86	128	28	46	.....	.....	.....
2	142	56	34	88	82	157	106	90	88	140	143	104	128	48	86	.....	.....	.....
3	146	80	38	87	69	163	108	101	90	139	134	121	116	66	84	84	.58	1.45
4	126	87	49	73	87	160	104	97	86	122	118	102	116	56	84	.68	.50	1.36
5	124	93	52	82	100	140	109	105	87	112	134	98	109	77	91	.52	.45	1.15
6	115	97	60	78	101	141	118	110	83	108	123	109	108	77	89	.52	.41	1.27
7	107	95	64	82	103	137	115	107	83	101	136	102	114	80	87	.48	.38	1.27
8	104	92	79	82	97	127	114	108	93	102	130	105	108	81	89	.38	.35	1.08
9	101	88	79	88	95	120	114	102	99	102	127	98	116	79	85	.37	.33	1.12
10	95	95	84	91	90	118	112	100	98	103	125	96	117	78	84	.36	.32	1.12
11	104	105	85	89	88	117	108	97	98	96	122	94	112	81	85	.33	.30	1.10
12	105	105	82	86	92	116	107	94	100	96	123	96	117	86	84	.34	.29	1.17
13	109	104	80	91	98	119	109	99	100	96	127	96	122	86	84	.34	.28	1.21
14	105	106	79	91	98	115	112	101	101	98	127	103	116	85	92	.29	.27	1.07
15	107	104	79	90	99	118	115	100	107	100	126	104	113	85	90	.30	.26	1.15
16	105	103	77	93	101	120	114	103	106	97	123	105	116	83	89	.30	.25	1.20
17	108	102	78	92	101	118	113	106	106	98	126	109	114	87	88	.31	.24	1.29

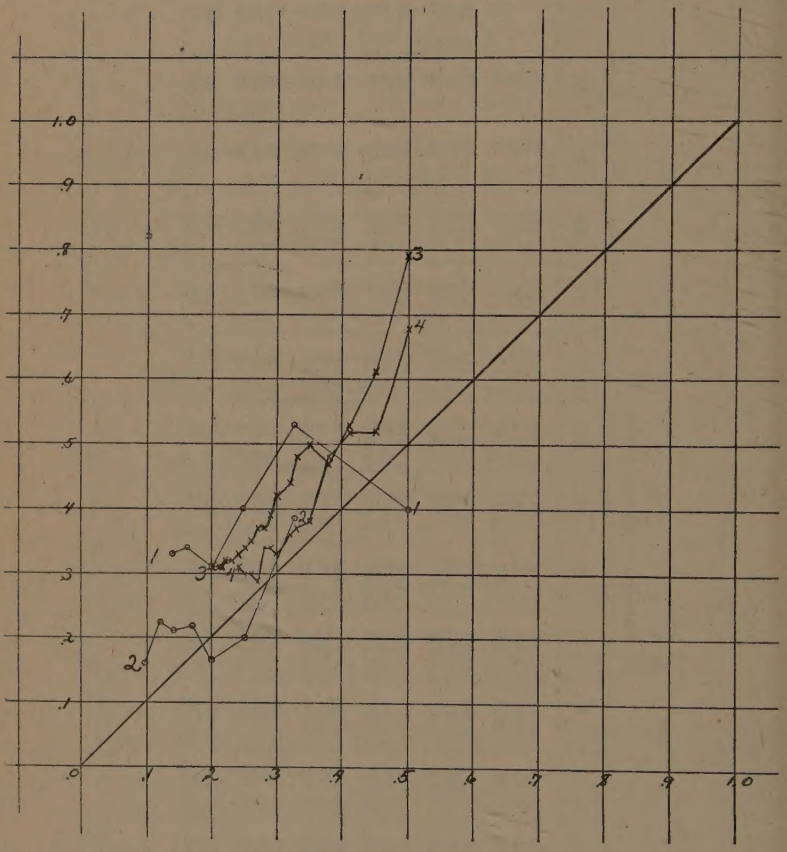

PLATE VII.—Application of Professor Marvin's periodocrites to various periodocrites.

1. Annual cycle, Washington, D. C., rainfall, fifty-year record.
2. Annual cycle, Boston rainfall, 103-year record.
3. Twenty-four cycles ninth harmonic of sun-spot period in Eastern group rainfall.
4. Seventeen cycles of same in Western group rainfall.

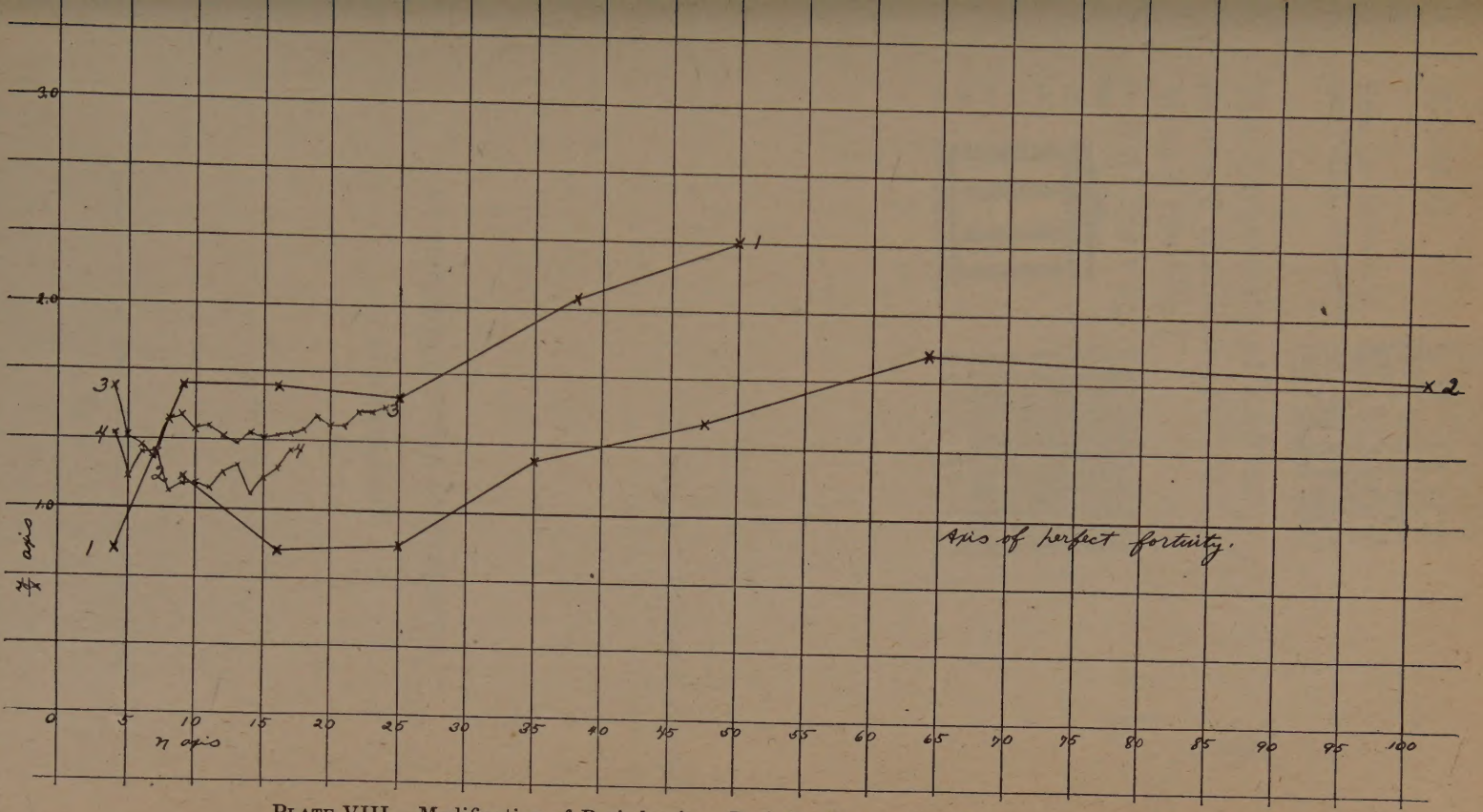

PLATE VIII.—Modification of Periodocrite. Periodocrites numbered same as in plate VII.